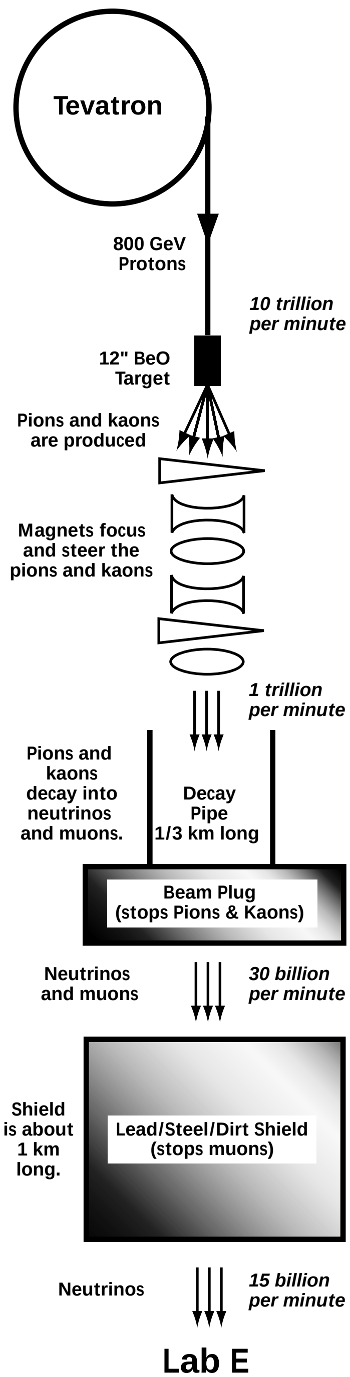
High Energy Physics

made painless

Fixed-Target Physics Part Deux

How E815 gets its neutrinos



(Observe about 15 interactions per minute.)

by Peter Garbincius, Physics Section, and Leila Belkora, Office of Public Affairs

As a pasta machine makes dough into long strands of spaghetti, pillows of ravioli, or curly mounds of rigatoni, depending on the attachments, so fixed-target experiments take a stream of protons and produce particle beams of whatever kind they need, using specialized targets and selection devices. At Fermilab, where nine fixed-target experiments are currently running, the menu includes beams of particles such as hyperons, neutral kaons, and the dieter's delight—the calorie-free neutrinos.

Primary protons from the Tevatron—the basic ingredient of all but two of the fixed-target experiments—hit targets to produce secondary beams. Some experiments use the secondary beams directly, while some require another stage to study particles that decay from them. In either case, the first choice experimenters make is what type of target to use.

The optimum target is one that favors producing the particles of interest, but does not absorb them. E872 needs neutrinos, elementary particles that react with matter so little that they can travel through the earth itself without being significantly absorbed. That experiment's target consists of a thick block of tungsten, in which pions materialize and decay into neutrinos. The rest of the beamline is mostly absorbent shielding, to take everything but the neutrinos out of the beam. E831, on the other hand, needs a beam of photons that would be completely absorbed by a metal target. Experimenters there chose liquid deuterium for their target because compared to metals it has a more favorable balance of charge and mass. The charge in the target particle absorbs and reconverts photons (bad for beam intensity), while a high mass favors producing photons (good for beam intensity).

Experimenters focus the primary proton beam down to a narrow spot illuminating their target. Again, they make trade-offs. The smallest spots give the most intense beams, but focusing the beams too strongly could melt the target.

Directly downstream from the target, experimenters select for the particles they're interested in. KTeV, for example, selects for the subatomic particles called neutral kaons. A magnetic field sweeps charged particles out of the way. The neutral kaons are not affected by magnetic fields, and emerge in all directions. Experimenters could position a detector in the straight-ahead direction to get the maximum number of kaons, but unwanted neutrons are also most numerous there, so they move to an angle where they get enough kaons, but not too many neutrons. At a wider angle they could get fewer neutrons—a smaller background to the signal—but they'd also get fewer kaons.

Experimenters make trade-offs in selecting a target, focusing the primary beam onto the target, and purifying the secondary beam, always seeking the strategy that will yield high signal and low background. They don't have as much choice, however, in where they position the detectors. The physical length of a fixed-target beamline is determined by the lifetime of the chosen particle. Some fixed-target experiments stretch over a kilometer or more. The Sigma-minuses used in E781 have a lifetime of 1.5×10^{-10} seconds, and travel about seven meters before decaying, so the experimental detectors are close to the target. The pions in E815 have a lifetime over a hundred times longer than that of the Sigma-minuses, and travel correspondingly farther before decaying.

The fixed-target experiments look very different from one another, and require specialized beams to achieve their physics goals. It's the technique for forming the beam that's the same. As one experimenter put it, you focus, you target, you make a selection, and you do something about your background.

Tutti mangia! ■